Identifying System Properties through Structural Inference using In-Service Measurements

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ABSTRACT

In many cases properties of offshore systems cannot be easily measured, yet knowledge thereof may be of importance to ensure safe operations. In this paper a data analysis technique is presented to identify these system properties through measurements of loads and responses. The theory is tested using in-service measurements of an FPSO. Wave and motion measurements are used to identify the load case that the FPSO operates in. Using a strongly simplified model to relate load and response, the procedure is able to achieve good accuracy. Multiple improvements to the method are discussed.

KEY WORDS: Inference; modeling; design uncertainties; monitoring; FPSO; motions.

INTRODUCTION

During their lifetime, ships and offshore units are subjected to many loads. Design procedures ensure structural integrity of these units. Typical failure modes that are assessed during the design are ultimate strength, fatigue and corrosion.

While being operated, ship and offshore units will experience degradation of their structural strength. Design procedures account for some degree of degradation, but the speed of structural degradation is subject to many parameters and in some cases hard to predict accurately (Qin and Cui, 2003). To ensure safe operations, ships are subjected to inspections at regular time intervals. Some offshore units are continuously being operated on station for a prolonged period of time. It is more difficult to execute thorough inspections for these units and the result is less accurate (Caldwell and Constantinis, 2013). Monitoring systems can be applied to monitor the loads and structural response over time. Combined with a consistent data analysis procedure, the performance of the unit can be compared with initial assumptions made during design (Hageman et al., 2013).

Although loads and response can be measured and analyzed, it is less straightforward and practical to measure the structural strength characteristics, such as plate thickness and coating integrity. However, these properties will degrade over time and as a result the safety of the unit will reduce. Structural inference can be used to identify changes to the structure through the comparison of load and response measurements. This allows the calculation of parameters that cannot be measured directly. One example of this technique is the identification of riser motions from top tension measurements (Lee and Gerretsen, 2011).

Loads and responses from in service measurements cannot be compared using a deterministic approach. The analysis of loads uses models and calculation procedures that contain some assumptions and approximations. These uncertainties can be significant and should be accounted for in the calculation model. Various studies have been conducted to identify different uncertainties. E.g. Moan et al. (2006) presents the effect of uncertainties in a reliability based ultimate strength assessment. Hageman et al. (2014) presents an overview and assessment of calculation uncertainties for fatigue assessment. In this study the uncertainty in the calculation of motions will be quantified.

For the different load cases a stochastic model for response calculation will be created. The model is composed of a linear regression analysis in combination with a probability function to describe the calculation uncertainties. The parameters of this model will be determined using in-service measurements.

Based on a series of load and response measurements, the model that describes these measurements in the best possible way will be selected. The quality of the inference of system properties is subject to several parameters. A parameter study is executed to investigate the accuracy and convergence of the inference procedure.

THEORETICAL BACKGROUND

A typical design process is shown in Fig.1. In order to calculate the response a number of input parameters need to be defined. These input parameters are then used to calculate the structures response while in operation. A number of the input parameters can be measured. Other parameters cannot be measured easily. Nonetheless, knowledge of these parameters is important for the calculation procedure.

If the input parameters during a certain time period are measured, these can be used to calculate the response in that same period. Assumptions